JOURNAL OF CLINICAL MICROBIOLOGY, June 2003, p. 2275–2278 Vol. 41, No. 6
0095-1137/03/$08.00+0 DOI: 10.1128/JCM.41.6.2275–2278.2003

MINIREVIEW

Blood Culture Contamination: Persisting Problems and Partial Progress

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Although it has been widely appreciated for many years among physicians and microbiologists that blood cultures are among the most important laboratory tests performed in the diagnosis of serious infections (35), it has become equally apparent in more recent years that contaminated blood cultures are common (25, 42), enormously costly (3, 29), and frequently confusing for clinicians (1, 12, 14, 26). Clinical studies of bloodstream infections over 3 decades have provided guidelines for differentiating true pathogens from contaminants or organisms of unknown significance (14, 18, 41, 42); however, a true "gold standard" for differentiating pathogens from contaminants does not exist (4, 25). Moreover, the most common blood culture contaminants, coagulase-negative staphylococci (CoNS), which were almost always such several decades ago (18, 41), now are pathogens more frequently (19, 25, 26, 42), and judging the clinical significance of this group of microorganisms in blood has proven to be especially problematic (1, 11, 22, 24, 26, 42; S. J. Peacock, I. C. Bowler, and D. W. Crook., Letter, Lancet **346:**191-192, 1995). This review focuses on how pathogen-contaminant decisions are made, the phenomenon of increasing contamination of blood cultures, potential methods for addressing high contamination rates, and practical laboratory approaches to the workup of likely contaminants.

TOOLS FOR INTERPRETING THE CLINICAL SIGNIFICANCE OF POSITIVE BLOOD CULTURES

A number of clinical and laboratory tools have been proposed to aid microbiologists and physicians in deciding whether a blood isolate is a pathogen or a contaminant. These include the identity of the microorganism itself; clinical features such as fever, leukocytosis, and results of imaging studies (available to the clinician but usually not to the microbiologist); the proportion of blood culture sets positive as a function of the number of sets obtained; the time it takes for growth to be detected once a blood culture is received in the laboratory; and the number of culture vials within a culture set that show growth. Some of these tools have proven to be quite useful, whereas others have not.

The identity of the microorganism that grows from a positive blood culture provides important interpretative information. MacGregor and Beaty (18) documented this observation in the early 1970s, and studies by my colleagues and I confirmed and updated the earlier findings (41, 42). A predictive model that assessed multiple variables also documented microorganism identity as an independent predictor (4). Microorganisms that always or nearly always (>90%) represent true bacteremia or fungemia include *Staphylococcus aureus*, *Streptococcus pneumoniae*, *Escherichia coli* and other members of the *Enterobacteriaceae*, *Pseudomonas aeruginosa*, and *Candida albicans* (42). Although published data from large studies with multiple isolates of the following organisms are lacking, it is my observation that *Streptococcus pyogenes*, *Streptococcus agalactiae*, *Listeria monocytogenes*, *Neisseria meningitidis*, *Neisseria gonorrhoeae*, *Haemophilus influenzae*, members of the *Bacteroides fragilis* group, *Candida* species other than *C. albicans*, and *Cryptococcus neoformans* always or virtually always represent true infection. In contrast, microorganisms such as *Corynebacterium* species, *Bacillus* species other than *B. anthracis*, and *Propionibacterium acnes* represent true bacteremia only rarely (42). Detection of CoNS, the most frequent of all blood culture isolates, can be especially vexing. These bacteria are most often contaminants, but they have taken on increased clinical importance as the etiologic agents of catheter-associated bacteremia and bacteremia in patients with vascular and other prostheses (19, 26, 42). Accordingly, one can no longer judge the clinical significance of a CoNS isolate solely on the basis of its identity. Similarly, the clinical significance of other microorganisms also cannot be judged based only their identity. For example, in a recent study, enterococci and viridans group streptococci were pathogens 78 and 38% of the time, respectively, and *Clostridium perfringens* most often (77%) was a contaminant, whereas other *Clostridium* species most often (80%) were pathogens (42).

The number of blood culture sets that grow microorganisms, especially when measured as a function of the total number obtained, has proved to be a useful aid in interpreting the clinical significance of positive blood cultures (18, 41, 42). In contrast to patients with endocarditis or other bloodstream infections, in whom all blood cultures or the majority thereof are positive, patients whose blood cultures grow contaminants usually have only a single blood culture (when two or more are obtained) that is positive (42). Although obvious, it bears emphasis that if only a single blood culture is obtained, the value

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of this tool ceases to exist; and this is but one reason (another being increased blood volume) that at least two blood culture specimens are recommended as standard practice (2, 23, 37). The value of obtaining more than a single blood culture is that it also assists in interpreting the clinical significance of positive results by virtue of the following calculation. If an institution has a baseline blood culture contamination rate of 3%, the probability of recovering the same organism in two culture sets from a patient, and of that organism being a contaminant, is less than 1 in 1,000 ($0.03 \times 0.03 = 0.0009$)!

A laboratory tool that has been used as an aid to differentiating clinically significant isolates from contaminants is assessment of the time necessary for microbial growth to occur (4). The underlying premise is that growth of pathogens, which are likely to be present in larger inocula, will be detected earlier than that of contaminants, which are likely to be present in much smaller quantities (18). Whereas this concept likely has validity, the degree of overlap in the detection times of true pathogens versus contaminants is such that this variable cannot be relied upon as a predictor of a true-positive culture (8). Moreover, with the wide use of continuously monitoring blood culture systems and the concomitant decrease in the time to detection of growth, the time difference between the detection of true pathogens and contaminants has been narrowed even further.

Some microbiologists and clinicians have used the number of culture bottles positive within a blood culture set as a guide to determine whether isolates represent true pathogens or contaminants. However, there now are published data, at least for CoNS, that show that this technique is not clinically useful (22; Peacock et al., letter). Although clinically significant CoNS may grow more often in multiple bottles within a set as opposed to a single bottle, and contaminants may more often grow in only one bottle of a set, the degree of overlap is such that for a given culture this information cannot predict clinical significance reliably (22; Peacock et al., letter). Accordingly, this criterion should not be used.

THE PARADOX OF INCREASING NUMBERS OF CONTAMINANTS

Despite numerous advances in blood culture methodology and systems in recent decades, some hospitals and laboratories have noted that an increasing proportion of blood culture isolates represent contamination compared with those in years past (42). There are several possible explanations for this unexpected observation. The newer continuously monitoring blood culture systems have improved algorithms for detecting microbial growth and may be detecting microorganisms present in low numbers that previously were missed. Moreover, several broth medium formulations such as the BACTEC Plus Resin media (Becton Dickinson, Sparks, Md.) and BacT/ALERT FN media (bioMerieux, Durham, N.C.) have been shown to have improved detection of staphylococci, including CoNS which most often are contaminants (10, 20, 28, 38, 40, 43, 45). Thus, the ability of new systems and media to detect these organisms, even when present in small numbers, may be responsible in part for the observed increase in the proportion of blood cultures with contaminants.

The increased use of central venous access catheters and utilization of these devices for the purpose of obtaining blood specimens for culture may also be contributing to the increased numbers of contaminated blood cultures. Several studies have documented increased contamination when blood cultures are obtained in this fashion (5, 6, 7; R. B. Sivadas, B. Vazirani, S. Mirrett, and M. P. Weinstein, Abstr. 101st Gen. Meet. Am. Soc. Microbiol., abstr. C10, 2001), perhaps because it is more difficult to sterilize these devices than it is the skin before blood is obtained. Although physicians and nurses may believe they are saving patients the pain of an extra needle stick when blood cultures are obtained from catheters rather than by venipuncture, they may actually be doing their patients and the health care system a disservice if contaminants are grown from the culture resulting in the need for even more cultures, other diagnostic studies, unnecessary antibiotic therapy, and the associated incremental costs of care.

Prior to the human immunodeficiency virus (HIV) era, blood cultures traditionally were obtained by a two-needle technique, using a sterile needle and syringe to perform the venipuncture, then changing to a second sterile needle before inoculating the blood culture vial. The purpose of the two-needle technique was to reduce the chance that skin microorganisms that might be present on the needle used for the venipuncture would be inoculated into the blood culture vial, thereby resulting in a contaminated blood culture. As the knowledge of HIV as a bloodborne pathogen and the risks of needle stick transmission of HIV became evident, several studies were undertaken to determine whether contamination rates would be affected if only one needle was used for both venipuncture and inoculation of blood culture vials (9, 15, 16). The results of each of these studies showed no significant increase in contamination rates when the single-needle technique was used. Subsequently, however, a meta-analysis suggested that single-needle blood cultures were associated with contamination rates of 3.7% compared with 2.0% when a two-needle technique was used (30). Since the current standard of care continues to be the single-needle technique in order to reduce the risk of occupational needle stick injuries, slightly higher contamination rates may have to be tolerated.

REDUCING THE NUMBER OF CONTAMINATED BLOOD CULTURES

Although it is not possible to achieve contamination rates of zero or even close to zero (31), there are potential means by which contamination can be reduced. These include the use of collection methods that increase the chances for sterility, for example, obtaining blood via venipuncture rather than from an intravascular catheter or using a two-needle rather than a single-needle technique, as has already been mentioned. For the reasons already stated, the two-needle method is unlikely to return to widespread use; however, laboratories and institutions can and should actively promote blood cultures obtained from venipuncture rather than intravascular devices as a means of practicing evidence-based medicine.

There is also evidence that some antiseptic preparations may be more efficacious than others in reducing contamination rates. Povidone iodine preparations require 1.5 to 2 min of contact time to produce their maximum antiseptic effect, whereas iodine tincture requires approximately 30 s (13). Health care

workers who obtain blood cultures are often in a hurry, do not understand the importance of antiseptic preparation contact time, and are less likely to wait 1.5 to 2 min as opposed to half a minute before obtaining blood. At least two studies have documented a significantly lower contamination rate using iodine tincture compared with an iodophor (17, 31). Another report compared the use of 0.2% chlorine peroxide and 10% povidone iodine and demonstrated lower contamination rates when chlorine peroxide was used (29). Lastly, an alcoholic solution of 0.5% chlorhexidine gluconate used as an antiseptic prior to blood culture was associated with significantly lower contamination rates compared with a standard povidone-iodine preparation (21).

Several published studies have shown that trained phlebotomists or blood culture teams can reduce contamination rates in individual institutions (27, 32, 36), and this has been confirmed in my own institution (Sivadas et al., 101st Gen. Meet. Am. Soc. Microbiol.). At a New York City, N.Y., community teaching hospital, the contamination rate for blood cultures drawn by a blood culture team using a commercially available blood culture prep kit was approximately 1% compared with rates of 4.8% for blood cultures drawn by resident physicians using the same method (36). The contamination rate when residents did not use the commercial prep kit was even higher (8.4%) (36). In a large survey of over 600 hospitals sponsored by the College of American Pathologists, median contamination rates for institutions in which more than half of all blood cultures were collected by resident physicians was 3.9%, compared with 2.2% in the remaining institutions (27). In a pilot study at my institution, contamination of blood cultures obtained by phlebotomists trained and monitored monthly by microbiology laboratory staff was 3%, compared with nearly 11% for blood cultures obtained by resident physicians, nondegree nursing assistants, and nurses (M. P. Weinstein, unpublished observation). Subsequently, my colleagues and I assessed contamination in a larger study and again found that samples collected by phlebotomists had lower contamination rates than those collected by nondegree nursing assistants, nurses, and resident physicians (the last of whose samples had the highest contamination rates) (Sivadas et al., 101st Gen. Meet. Am. Soc. Microbiol.).

Whether or not commercially marketed blood culture prep kits are associated with reduced blood culture contamination rates remains controversial. Some studies have shown reduced contamination (27, 36) with commercial prep kits, whereas others have shown no difference (44). The manufacturer of at least one commercial prep kit has offered ongoing in-service education for personnel obtaining blood cultures (M. P. Weinstein, personal observation), which itself may be associated with reduced contamination rates.

LABORATORY WORKUP OF LIKELY BLOOD CULTURE CONTAMINANTS

In the real world of clinical microbiology laboratories, nearly half of all positive blood cultures represent contamination (42). Complete laboratory workup of contaminant isolates is associated with increased technologist workload and institutional cost. Therefore, some laboratories have developed algorithms for dealing with this problem based, at least in part, on many of the studies reviewed in this article.

At the University of Iowa, for example, Richter et al. (25) tested, validated, and implemented an algorithm to minimize the workup of blood culture contaminants. CoNS, aerobic and anaerobic diphtheroids, *Micrococcus* spp., *Bacillus* spp., and viridans group streptococci are considered contaminants if certain criteria are met. If two or more blood cultures are obtained and only one is positive, the isolate is reported as a probable contaminant and susceptibility testing is not done unless the physician calls the laboratory. If only a single blood culture is obtained and grows one of the likely contaminants, a pathology resident reviews the patient's chart and judges the clinical significance of the isolate based on published data (42). Susceptibility testing is not done if the isolate is judged to be a contaminant. If two or more blood cultures are obtained and two cultures are positive within a 48-h period, one of two actions is taken. If the isolates are viridans group streptococci, they are presumed to be clinically significant and a full workup is done. If one of the other likely contaminants is present, the pathology resident reviews the patient's chart, and the laboratory workup proceeds according to the resident's judgment regarding clinical significance.

In my laboratory, a similar protocol is followed, but it is modified somewhat based on the fact that pathology residents are not always assigned to microbiology. The same microorganisms are considered likely contaminants. If two or more blood cultures are submitted and only one is positive, neither species identification nor susceptibility testing is done; the isolate is reported as a probable contaminant. If only one blood culture is submitted and it grows a likely contaminant, the workup is the same; the isolate is reported to be of indeterminate significance and the physician is advised to call the laboratory director if additional workup is needed. If two or more blood cultures grow a likely contaminant other than CoNS (see below) within a 48-h period, a full workup is done. If the isolates are the same, the identification and susceptibility results are reported. If the isolates are different, they are reported as probable contaminants without susceptibility results.

When two or more blood cultures grow CoNS, my laboratory undertakes species identification and reports susceptibility results. I find that the additional information assists in determining whether the isolates are clinically significant (12, 39). If the strains isolated have the same biochemical profile and antibiogram, it is probable that they are identical (although only molecular typing provides proof). This information increases the likelihood that the isolates represent clinically significant bacteremia, and identification and susceptibility results are reported to the clinician. However, if the biochemical profiles and antibiograms are not the same (i.e., two or more differences in biochemical results and susceptibilities [susceptible versus resistant]), the isolates are much more likely to represent contamination. In this instance, the laboratory reports that two different CoNS strains were identified, and susceptibility results are not provided. Although this technique has proven clinically useful in most circumstances, the algorithm is not foolproof. Two studies from the same center in Belgium have described polyclonal CoNS bacteremia (33, 34). Thus, in patients who have multiple positive blood cultures growing CoNS that appear to be different strains, the labora-

tory may need to perform additional testing if clinicians believe clinically significant infection is present.

As is apparent from the foregoing discussion, the current state of the art remains suboptimal. Although progress has been made, the interpretation of the clinical significance of microorganisms that are common blood culture contaminants and the technical effort and institutional costs associated with working up probable contaminants remain problematic. Gold standards for solving these problems still are elusive.

REFERENCES

1. **Archer, G. L.** 1985. Coagulase-negative staphylococci in blood cultures: the clinician's dilemma. Infect. Control **6:**477–478.
2. **Aronson, M., and D. Bor.** 1987. Blood cultures. Ann. Intern. Med. **106:**246–253.
3. **Bates, D. W., L. Goldman, and T. H. Lee.** 1991. Contaminant blood cultures and resource utilization: the true consequences of false-positive results. JAMA **265:**365–369.
4. **Bates, D. W., and T. H. Lee.** 1992. Rapid classification of positive blood cultures: prospective validation of a multivariate algorithm. JAMA **267:** 1962–1966.
5. **Bryant, J. K., and C. L. Strand.** 1987. Reliability of blood cultures collected from intravascular catheter versus venipuncture. Am. J Clin. Pathol. **88:**113–116.
6. **DesJardin, J. A., M. A. Falagas, R. Ruthazer, J. Griffith, D. Wawrose, D. Schenkein, K. Miller, and D. R. Snydman.** 1999. Clinical utility of blood cultures drawn from indwelling central venous catheters in hospitalized patients with cancer. Ann. Intern. Med. **131:**631–647.
7. **Everts, R. J., E. N. Vinson, P. O. Adholla, and L. B. Reller.** 2001. Contamination of catheter-drawn blood cultures. J. Clin. Microbiol. **39:**3393–3394.
8. **Ilstrup, D.** 1978. Sepsis: organisms from blood culture at the Mayo Clinic: 1968–1975, p. 23–25. *In* J. Washington II (ed.), The detection of septicemia. CRC Press, West Palm Beach, Fla.
9. **Isaacman, D., and R. Karasic.** 1990. Lack of effect of changing needles on contamination of blood cultures. Pediatr. Infect. Dis. J. **9:**274–278.
10. **Jorgensen, J. H., S. Mirrett, L. C. McDonald, P. R. Murray, M. P. Weinstein, J. Fune, C. W. Trippy, M. Masterson, and L. B. Reller.** 1997. Controlled clinical laboratory comparison of BACTEC Plus Aerobic/F resin medium with BacT/Alert Aerobic FAN medium for detection of bacteremia and fungemia. J. Clin. Microbiol. **35:**53–58.
11. **Khatib, R., K. M. Riederer, J. A. Clarck, S. Khatib, L. E. Briski, and F. M. Wilson.** 1995. Coagulase-negative staphylococci in multiple blood cultures: strain relatedness and determinants of same-strain bacteremia. J. Clin. Microbiol. **33:**816–820.
12. **Kim S-D., L. C. McDonald, W. R. Jarvis, S. K. McAllister, R. Jerris, L. A. Carson, and J. M. Miller.** 2000. Determining the significance of coagulase-negative staphylococci isolated from blood cultures at a community hospital: a role for species and strain identification. Infect. Control Hosp. Epidemiol. **21:**213–217.
13. **King, T. C., and P. B. Price.** 1963. An evaluation of iodophors as skin antiseptics. Surg. Gynecol. Obstet. **116:**361–365.
14. **Kirchhoff, L. V., and J. N. Sheagren.** 1985. Epidemiology and clinical significance of blood cultures positive for coagulase-negative staphylococcus. Infect. Control **6:**479–486.
15. **Krumholz, H. M., S. Cummings, and M. York.** 1990. Blood culture phlebotomy: switching needles does not prevent contamination. Ann. Intern. Med. **113:**290–292.
16. **Leisure, M. K., D. M. Moore, J. D. Schwartzman, G. F. Hayden, and L. G. Donowitz.** 1990. Changing the needle when inoculating blood cultures: a no-benefit and high-risk procedure. JAMA **264:**2111–2112.
17. **Little, J. R., P. R. Murray, P. S. Traynor, and E. Spitznagel.** 1999. A randomized trial of povidone-iodine compared with iodine tincture for venipuncture site disinfection: effects on rates of blood culture contamination. Am. J. Med. **107:**119–125.
18. **MacGregor, R. R., and H. N. Beaty.** 1972. Evaluation of positive blood cultures. Guidelines for early differentiation of contaminated from valid positive cultures. Arch. Intern. Med. **130:**84–87.
19. **Martin, M. A., M. A. Pfaller, and R. P. Wenzel.** 1989. Coagulase-negative staphylococcal bacteremia: mortality and hospital stay. Ann. Intern. Med. **110:**9–16.
20. **McDonald, L. C., J. Fune, L. D. Guido, M. P. Weinstein, L. G. Reimer, T. M. Flynn, M. L. Wilson, S. Mirrett, and L. B. Reller.** 1996. Clinical importance of the increased sensitivity of BacT/Alert FAN aerobic and anaerobic blood culture bottles. J. Clin. Microbiol. **34:**2180–2184.
21. **Mimoz, O., A. Karim, A. Mercat, M. Cosseron, B. Falissard, F. Parker, C. Richard, K. Samii, and P. Nordmann.** 1999. Chlorhexidine compared with povidone-iodine as skin preparation before blood culture: a randomized controlled trial. Ann. Intern. Med. **131:**834–837.
22. **Mirrett, S., M. P. Weinstein, L. G. Reimer, M. L. Wilson, and L. B. Reller.** 2001. Relevance of the number of positive bottles in determining clinical significance of coagulase-negative staphylococci in blood cultures. J. Clin. Microbiol. **39:**3279–3281.
23. **Reimer, L. G., M. P. Weinstein, and M. L. Wilson.** 1997. Update on the detection of bacteremia and fungemia. Clin. Microbiol. Rev. **10:**444–465.
24. **Reller, L. B.** 1996. Introduction. Clin. Infect. Dis. **23:**38–39.
25. **Richter, S. S., S. E. Beekmann, J. L. Croco, D. J. Diekema, F. P. Koontz, M. A. Pfaller, and G. V. Doern.** 2002. Minimizing the workup of blood culture contaminants: implementation and evaluation of a laboratory-based algorithm. J. Clin. Microbiol. **40:**2437–2444.
26. **Rupp, M. E., and G. L. Archer.** 1994. Coagulase-negative staphylococci: pathogens associated with medical progress. Clin. Infect. Dis. **19:**231–243.
27. **Schifman, R. B., and A. Pindur.** 1993. The effect of skin disinfection materials on reducing blood culture contamination. Am. J. Clin. Pathol. **99:**536–538.
28. **Smith, J. A., E. A. Bryce, J. H. Ngui-yen, and F. J. Roberts.** 1995. Comparison of BACTEC 9240 and BacT/Alert blood culture systems in an adult hospital. J. Clin. Microbiol. **33:**1905–1908.
29. **Souvenir, D., D. E. Anderson, Jr., S. Palpant, H. Mroch, S. Askin, J. Anderson, J. Claridge, J. Eiland, C. Malone, M. W. Garrison, P. Watson, and D. M. Campbell.** 1998. Blood cultures positive for coagulase-negative staphylococci: antisepsis, pseudobacteremia, and therapy of patients. J. Clin. Microbiol. **36:**1923–1926.
30. **Spitalnic, S. J., R. H. Wollard, and L. A. Mermel.** 1995. The significance of changing needles when inoculating blood cultures: a meta-analysis. Clin. Infect. Dis. **21:**1003–1006.
31. **Strand, C. L., R. R. Wajsbort, and K. Sturmann.** 1993. Effect of iodophor vs. iodine tincture skin preparation on blood culture contamination rate. JAMA **269:**1004–1006.
32. **Surdulescu, S., D. Utamsingh, and R. Shekar.** 1998. Phlebotomy teams reduce blood culture contamination rate and save money. Clin. Perform. Qual. Health Care **6:**60–62.
33. **Van Eldere, J., W. E. Peetermans, M. Struelens, A. Deplano, and H. Bobbaers.** 2000. Polyclonal staphylococcal endocarditis caused by genetic variability. Clin. Infect. Dis. **31:**24–30.
34. **Van Wijngaerden, E., W. E. Peeteremans, S. Van Lierde, and J. Van Eldere.** 1997. Polyclonal staphylococcus endocarditis. Clin. Infect. Dis. **25:**69–71.
35. **Washington, J. A.** 1975. Blood cultures: principles and techniques. Mayo Clin. Proc. **50:**91–97.
36. **Weinbaum, F. I., S. Lavie, M. Danek, D. Sixsmith, G. F. Heinrich, and S. S. Mills.** 1997. Doing it right the first time: quality improvement and the contaminant blood culture. J. Clin. Microbiol. **35:**563–565.
37. **Weinstein, M. P.** 1996. Current blood culture methods and systems: clinical concepts, technology, and interpretation of results. Clin. Infect. Dis. **23:**40–46.
38. **Weinstein, M. P., S. Mirrett, L. G. Reimer, M. L. Wilson, S. Smith-Elekes, C. R. Chuard, K. L. Joho, and L. B. Reller.** 1995. Controlled evaluation of BacT/Alert standard aerobic and FAN aerobic blood culture bottles for detection of bacteremia and fungemia. J. Clin. Microbiol. **33:**978–981.
39. **Weinstein, M. P., S. Mirrett, L. Van Pelt, M. McKinnon, B. L. Zimmer, W. E. Kloos, and L. B. Reller.** 1998. Clinical importance of identifying coagulase-negative staphylococci from blood cultures: evaluation of MicroScan Rapid and Dried Overnight Gram-positive panels versus a conventional reference method. J. Clin. Microbiol. **36:**2089–2092.
40. **Weinstein, M. P., S. Mirrett, M. L. Wilson, L. J. Harrell, C. W. Stratton, and L. B. Reller.** 1991. Controlled evaluation of BACTEC Plus 26 and Roche Septi-Chek aerobic blood culture bottles. J. Clin. Microbiol. **29:**879–882.
41. **Weinstein, M. P., L. B. Reller, J. R. Murphy, and K. A. Lichtenstein.** 1983. The clinical significance of positive blood cultures: a comprehensive analysis of 500 episodes of bacteremia and fungemia in adults. I. Laboratory and epidemiologic observations. Rev. Infect. Dis. **5:**35–53.
42. **Weinstein, M. P., M. L. Towns, S. M. Quartey, S. Mirrett, L. G. Reimer, G. Parmagiani, and L. B. Reller.** 1997. The clinical significance of positive blood cultures in the 1990s: a prospective comprehensive evaluation of the microbiology, epidemiology, and outcome of bacteremia and fungemia in adults. Clin. Infect. Dis. **24:**584–602.
43. **Wilson, M. L., S. Mirrett, F. T. Meredith, M. P. Weinstein, V. Scotto, and L. B. Reller.** 2001. Controlled clinical comparison of BACTEC Plus Anaerobic/F versus Standard Anaerobic/F blood culture bottles for the detection of bacteremia and fungemia in adults. J. Clin. Microbiol. **39:**983–989.
44. **Wilson, M. L., M. P. Weinstein, S. Mirrett, L. G. Reimer, C. Fernando, F. T. Meredith, and L. B. Reller.** 2000. Comparison of iodophor and alcohol pledgets versus the Medi-Flex Blood Culture Prep Kit II for preventing contamination of blood cultures. J. Clin. Microbiol. **38:**4665–4667.
45. **Wilson, M. L., M. P. Weinstein, S. Mirrett, L. G. Reimer, S. Smith-Elekes, C. R. Chuard, and L. B. Reller.** 1995. Controlled evaluation of BacT/Alert standard anaerobic and FAN anaerobic blood culture bottles for the detection of bacteremia and fungemia. J. Clin. Microbiol. **33:**2265–2270.